Fermi National Accelerator Laboratory

Recent QCD Results from CDF

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ABSTRACT

CDF has recently concluded a very successful 1992-93 data run in which an integrated luminosity of 21.3 pb^{-1} was written to tape. The large data sample allows for a greater discovery potential for new phenomena and for better statistical and systematic precision in analysis of conventional physics. This paper summarizes some of the new results from QCD analyses for this run.

1.   Jets

1.1   Inclusive Jet Cross Section

The inclusive jet cross section is shown in Figure 1 for jets in the central region of rapidity (0.1 <|η|< 0.7) for a sample corresponding to 15 pb^{-1}. A cone size of 0.7 has been used in the jet reconstruction algorithm and the jet energies have been corrected for detector effects (but not for fragmentation outside of the cone). The increased statistics (relative to the 1989 data sample) allow for a greater reach in transverse energy. In addition, the use of minimum bias trigger data allows the inclusive cross section to be measured down to a transverse momentum of 15 GeV/c. Agreement with a NLO calculation is seen over the entire range with some trend towards a cross section larger than predicted at the very highest transverse energies.[1] For comparison purposes, a second curve is shown that includes a contact term corresponding to a compositeness scale of 1.4 TeV (the 1989 limit).[2]

1.2   Dijets

More information is available from the event if one measures the rapidities of both jets. In Figure 2, the trigger jet is required to be in the central region (0.1<|η|<0.7) while the probe jet is allowed to range over a rapidity interval of ±3. The cross section for different η_{jet2} intervals is plotted versus the E_T of the central jet (jet1). The agreement with a LO calculation is satisfactory except at large η_{jet2} and large E_T. However, this is the region where where NLO corrections will have the largest effect.[3] The NLO calculations for this cross section will soon become available allowing for a more quantitative comparison.   Note that the last E_T bin for 2.0<|η|<3.0 probes parton distributions at very high x (>0.7).

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1.   This region in ET probes large enough values of x that a resummation calculation may be necessary to correctly describe the cross section.

2.   F. Abe et al, Phys. Rev. Lett., Vol. 68, Num. 8(1992) 1104.

3.   S. Ellis, comment at the Workshop on QCD at 2 TeV, Michigan State U., Oct. 1993.

A good handle on parton distributions at low x can be obtained by measuring the dijet cross section where both jets are at large rapidities (on the same side of the detector). The kinematics forces the x value of one colliding parton to be large and the other to be very small. For example, for an E_T of 30 GeV/c and rapidity (of both jets) of 2.5, the momentum fraction of the low x parton is 0.003. Parton distributions (essentially the gluon) are poorly determined at this low of an x-value.

Some of the systematic errors, both theoretical and experimental will cancel if one takes the ratio of the cross section where $\eta_{jet1}=\eta_{jet2}$ (SS) to the cross section where $\eta_{jet1}=-\eta_{jet2}$ (OS). The latter cross section will probe parton distributions at more moderate values of x. The ratio SS/OS is plotted in Figure 3 as a funtion of jet rapidity for the E_T range from 27 GeV/c to 60 GeV/c. The plot is for a sample of the data corresponding to 9.5 pb^{-1} (but using a very prescaled trigger). Also shown are leading order QCD comparisons using various parton distributions. If the gluon is singular as x approaches 0, one expects this ratio to become large at large η. A forward dijet trigger was implemented late in the 1992-93 run which should allow for a factor of 16 more data than shown in the above plot. Note also that if one can include jets (from the minimum bias sample) with an E_T of 10 GeV/c and an η of 3, then x values as low as 7 X 10^{-4} can be probed.

2.   Photons

2.1   Inclusive Photons

The central ($|\eta|<0.9$) cross section from the 1992-93 run is shown in Figure 4. The measurement ranges from a transverse momentum of 10 GeV/c to over 100 GeV/c. The photons are required to be isolated with an E_T of less than 4 GeV/c inside of a cone of radius (R) of 0.7 centered on the photon direction. This isolation requirement reduces the background from π^0 production by over one order of magnitude and in addition suppresses photon production from Bremsstrahlung processes. Two techniques were used for the extraction of the photon signal from the multi-photon background. The first technique examines the profile of the electromagnetic shower in the shower max detector embedded in the central electromagnetic calorimeter. The profile from a single photon tends to be narrower than those from the multi-photon background (primarily π^0's). By examining the $\chi 2$ distributions the level of single photon production can be extracted. This technique is ineffective at large transverse momenta (> 40 GeV), as the two photons from a π^0 coalesce and produce electromagnetic showers that completely mimic those from single photons. The second technique has no E_T limitation. In this technique, a preshower detector located immediately in front of the electromagnetic calorimeter is used to measure the percentage of single photon candidates that had converted in the (~1 X_0) magnet coil. This conversion probability is greater from the multi-photon background than for the single photon signal. Again, the level of direct photons can be extracted on a statistical basis.

In Figure 4, the photon cross section is compared to a NLO QCD calculation with CTEQ1M parton distributions and two choices of the renormalization/factorization scale. In Fig. 5, a linear plot of (Data-Theory)/Theory indicates a disagreement between theory and experiment at low and high values of p_T. (Statistical errors only are shown in the plot. The systematic error is roughly 20% for p_T>18 GeV/c, where the conversion technique is used, and varies from 20% to 60% for p_T<18 GeV/c, where the profile technique is used. The size of this systematic error is expected to decrease with further study.) This disagreement may be due to the shape of the gluon distribution and/or an increased amount

of Bremsstrahlung (over what the theory predicts) at small p_T. Systematic investigations are underway on the implications of this disagreement for the gluon distribution.[4]

2.2 Excited Quarks

The photon data sample was also used in a search for excited quark states with the excited quark producing a photon and a jet in the final state. The photon candidate + jet mass spectrum is shown in Fig. 6. The photon candidate + jet mass mass spectrum (measured in the region $|\eta_\gamma| < 0.9$ and $|\cos \theta^*| < 2/3$) is in good agreement with QCD predictions. An upper limit of 460 GeV/c^2 (at the 95% confidence level) can be placed on the mass of such an excited quark state. If used in conjunction with events with a W + jet final state, the limit can be increased to 540 GeV/c^2.[5]

3. High Sum E_T

Any new physics beyond the standard model might show up in events with the highest transverse energy. In Fig. 7, the ΣE_T cross section is shown for the 1992-93 data along with the predictions from Herwig (+a detector simulation). Herwig seems to provide an adequate description of the data over the entire ΣE_T range. In this data sample, however, are several interesting events at high ΣE_T with two photons in the final state. One such event is shown in Fig. 8. The total E_T in the event is approximately 450 GeV/c and the $\gamma\gamma$ mass is 375 GeV/c^2. The integrated ΣE_T distributions (in an 18 pb^{-1} sample) are shown in Fig. 9 for events containing two photons. (Each photon is required to be isolated with an additional E_T of less than 15% of the E_T of the photon within a cone of radius 0.7. The ΣE_T plotted in Fig. 9 includes the E_T of any jets that may be present,if the jet has a p_T greater than 20 GeV/c.) Also shown is a phenomenological prediction. The prediction includes the NLO calculation of the two photon (+jet) cross section, and an estimate of the background to the two photon signal. Note that the background becomes extremely small at high sum E_T. This is to be expected since it's very difficult for a high E_T jet to mimic an isolated photon. To describe the data at low ΣE_T, a "K-factor" of 2 is necessary. The shape of the phenomenological prediction agrees with the data except for the two events at very high ΣE_T. (A similar type of event with ΣE_T of about 500 GeV/c was seen in the 1989 data sample.) The data from Run Ib (expected to be 75 pb^{-1}) should determine whether these events are a statistical fluke or possible evidence of new physics.

4. Conclusion

Results have been presented from QCD analyses of data from the 1992-93 data run of CDF.

4.   This study is being conducted by a subset of the CTEQ collaboration.
5.   F. Abe et al., Fermilab-PUB-93/341-E, submitted to Phys. Rev. Lett.
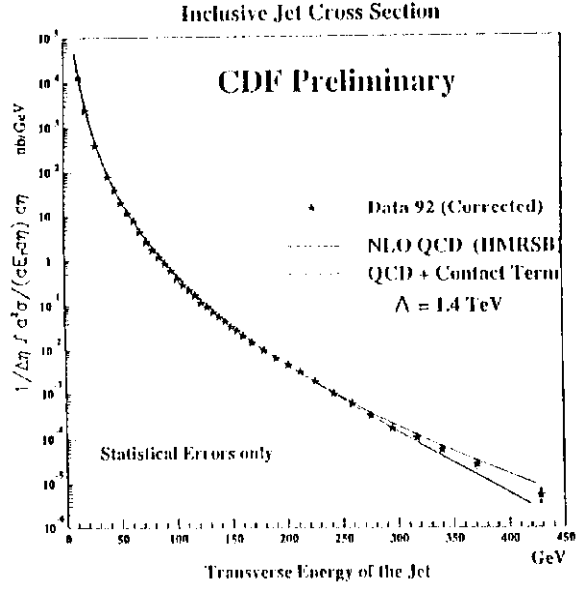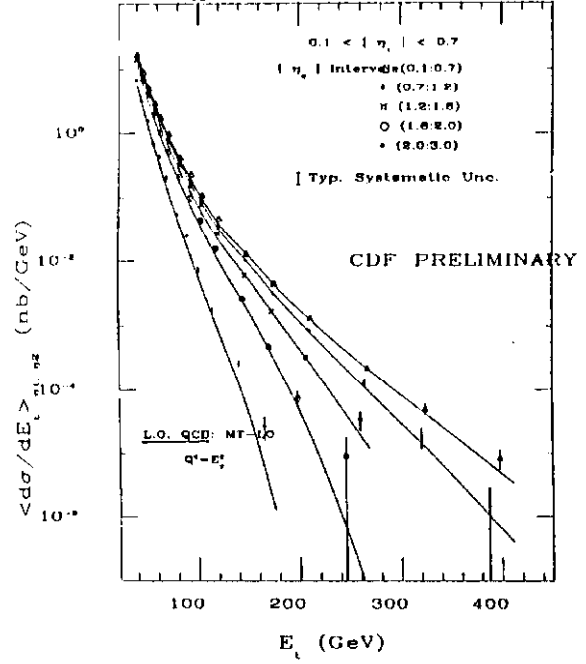
FIGURES

Inclusive Jet Cross Section
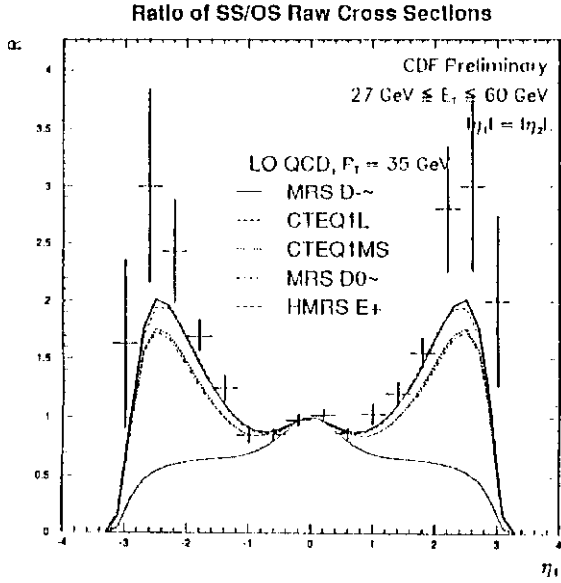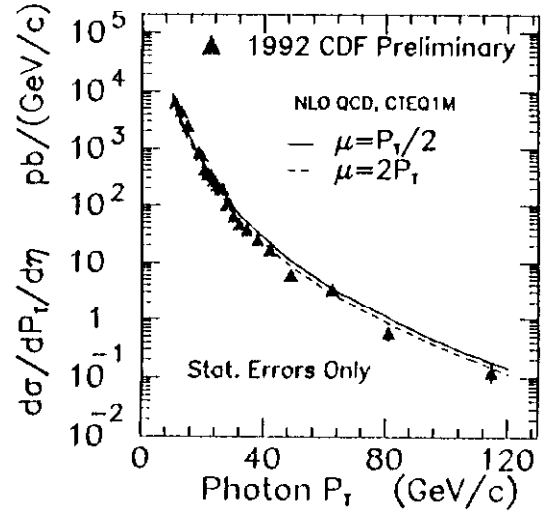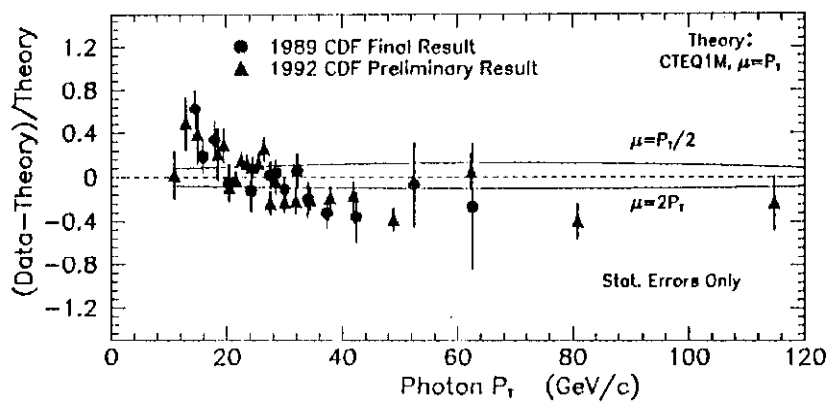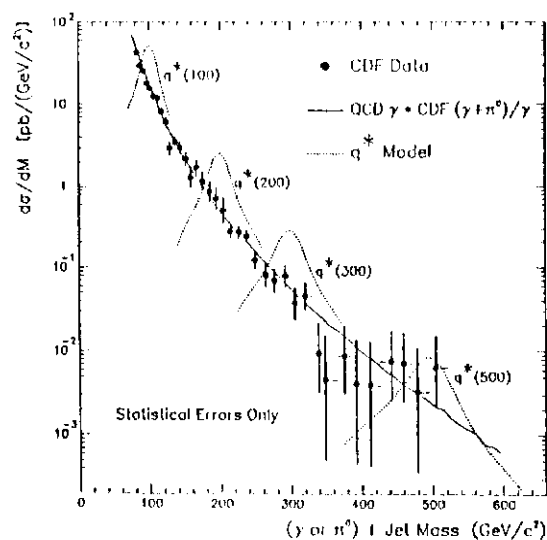

Figure 1.

Figure 2.

Ratio of SS/OS Raw Cross Sections

Figure 3.
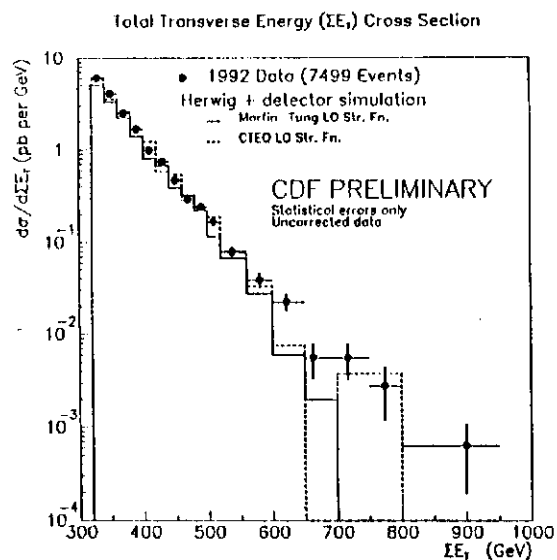

Figure 4.

Figure 5.

Figure 6.

Total Transverse Energy (ΣE_t) Cross Section

Figure 7.

Figure 8.

Figure 9.